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Establishing the minimal number of virtual reality simulator training sessions necessary to develop basic laparoscopic skills competence: evaluation of the learning curve

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ABSTRACT

Introduction: Medical literature is scarce on information to define a basic skills training program for laparoscopic surgery (peg and transferring, cutting, clipping). The aim of this study was to determine the minimal number of simulator sessions of basic laparoscopic tasks necessary to elaborate an optimal virtual reality training curriculum.
Materials and Methods: Eleven medical students with no previous laparoscopic experience were spontaneously enrolled. They were submitted to simulator training sessions starting at level 1 (Immersion Lap VR, San Jose, CA), including sequentially camera handling, peg and transfer, clipping and cutting. Each student trained twice a week until 10 sessions were completed. The score indexes were registered and analyzed. The total of errors of the evaluation sequences (camera, peg and transfer, clipping and cutting) were computed and thereafter, they were correlated to the total of items evaluated in each step, resulting in a success percent ratio for each student for each set of each completed session. Thereafter, we computed the cumulative success rate in 10 sessions, obtaining an analysis of the learning process. By non-linear regression the learning curve was analyzed.
Results: By the non-linear regression method the learning curve was analyzed and a $r^2 = 0.73$ ($p < 0.001$) was obtained, being necessary 4.26 (~five sessions) to reach the plateau of 80% of the estimated acquired knowledge, being that 100% of the students have reached this level of skills. From the fifth session till the 10th, the gain of knowledge was not significant, although some students reached 96% of the expected improvement.
Conclusions: This study revealed that after five simulator training sequential sessions the students' learning curve reaches a plateau. The forward sessions in the same difficult level do not promote any improvement in laparoscopic basic surgical skills, and the students should be introduced to a more difficult training tasks level.

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INTRODUCTION

Since 1991, when the first laparoscopic nephrectomy was performed, until our days, a substantial number of laparoscopic procedures became the gold standard in urologic surgery. However, to the surgeon become able to perform these techniques, a training period of time is necessary to ameliorate their skills: the learning curve. This learning curve is defined as the number of times a procedure must to be repeated in order to reach a plateau of excellence and high quality expertise (1).

During the training period the new surgeons need to repeat the surgical procedures as many times as necessary to obtain the ability with the instruments. Actually, the challenge is to make this skills development period the most effective as possible.

Many reports have demonstrated that a high quality laparoscopic training program must include theoretical and practical activities, including manual and virtual simulators ("dry lab") and in animals ("wet lab"), before starting operating human subjects (2,3).

Simulator training is well recognized to be a fundamental tool in laparoscopy learning process. However, the evaluation of the trainee's competence achievement and the ability to perform laparoscopic surgery in human beings and how to validate the training programs for the many simulators available in our days are still missing (4-6). Medical literature is also scarce on information to define a basic skills training program for laparoscopic surgery (peg and transferring, cutting, clipping).

The aim of this study was to determine the minimal number of simulator sessions in basic laparoscopic skills necessary to elaborate an optimal Virtual Reality training curriculum.

MATERIALS AND METHODS

Eleven fourth-year medical students with no previous experience in laparoscopy were spontaneously enrolled in the study. They were submitted to virtual reality simulator training sessions starting level (Immersion Lap VR, San Jose, CA) (Figure-1),

Figure 1 - The Virtual Simulator -Immersion Lap VR, San Jose, CA.

including the sequence of camera handling, peg and transfer, clipping and cutting (Figure-2). Each student trained twice a week until 10 sessions were completed. The score indexes were registered and analyzed (Table-1).

Figure 2 -The students were submitted to simulator training sessions starting at level 1 (Immersion Lap VR, San Jose, CA), including sequentially camera handling (a), peg and transfer (b), clipping (c) and cutting (d). Each student trained twice a week until 10 sessions were completed. The score indexes were registered and analyzed.

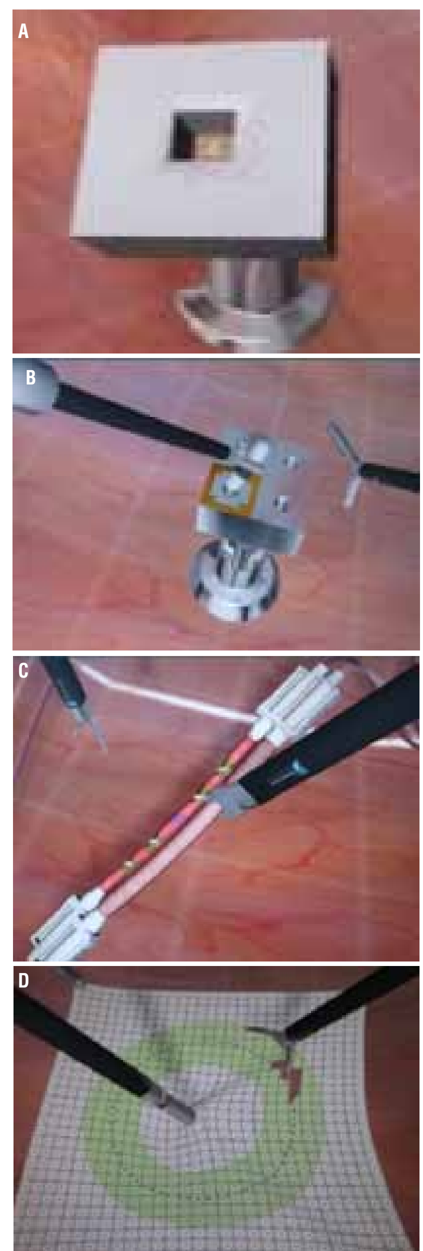


Table 1 (A.B.C.D) - List of basic procedures to be performed by the medical students: camera handling, peg and transfer, cutting and clipping. These procedures are in the simulator program.

Camera handling	Yes	No
Total time to complete task exceeded		
Average time to find object exceeded		
Task time limit exceeded		
Total camera path length exceeded		
Average camera path length exceeded		
Average camera rotation exceeded		
Percentage of time horizon maintained not completed		
Maximum horizon degree deviation exceeded		
Lens angle changes exceeded		
Number of collisions exceeded		
Found objects properly		
Not found objects properly		
Virtual assistance aid exceeded		

Table 1A

Peg and transfer	Yes	No
Total time to complete task exceeded		
Exceeded task time limit		
Average time to complete left hand task exceeded		
Average time to complete right hand task exceeded		
All active pegs not placed in allotted time		
Number of lost pins exceeded		
Right hand to left hand ratio $\neq 1$		
Number of lost pins with left hand exceeded		
Total number of dropped pegs exceeded		
Number of dropped pegs with right hand exceeded		
Number of dropped pegs with left hand exceeded		
Number of broken pegs exceeded		
Total number of next pegs exceeded		
Left hand total path length exceeded		
Right hand total path length exceeded		
Left hand path length with peg exceeded		
Right hand path length with peg exceeded		
Left hand path length without peg exceeded		
Right hand path length with peg exceeded		
Virtual assistance needed		

Table 1B

Cutting	Yes	No
Exceeded task time limit		
Lower than the max portion of cloth cut		
More than the minimal portion of cloth cut		
Complete pattern cut not completed		
Did cloth come loose from clips?		
Percentage cutting out of boundary area with right hand exceeded		
Percentage cutting out of boundary area with left hand exceeded		
Greatest distance out of cutting boundary with left hand exceeded		
Greatest distance out of cutting boundary with right hand exceeded		
Number of unsuccessful cutting attempts with left hand exceeded		
Number of unsuccessful cutting attempts with right hand exceeded		
Virtual aid usage		

Table 1C

Clipping	Yes	No
Time to complete task exceeded		
Total left hand path exceeded		
Total right hand path exceeded		
Blood loss		
Dropped clips left hand exceeded		
Dropped clips right hand exceeded		
Vessel perforated?		
Duct ligated or perforated?		
Clips placed too close?		
Maximum vessel stretch exceeded		
Clips applied in marked areas		
Correct number of clips placed in the marked area with left hand		
Correct number of clips placed in the marked area with right hand		
Misplaced clips left hand		
Misplaced clips right hand		
Cutting in the marked area		
Virtual assistance needed		

Table 1D

Statistical analysis: Initially, the total of errors of the four evaluation sequences (camera, peg and transfer, clipping and cutting) were computed and thereafter, they were corrected by the total of items evaluated in each step, resulting in a percent ratio of success for each student for each set of each completed session (Friedman Repeated Measures test). Thereafter, we computed the number of cumulative successful tasks in 10 sessions, obtaining an estocastic analysis of the learning process (Dunnett's Method). By non-linear regression the learning curve was analyzed.

RESULTS

Median values and quartiles of the obtained scores were computed in each training session (Table-2). By the non-linear regression method the learning curve was analyzed and an $r2 = 0.73$ ($p < 0.001$) was obtained, being the double half-of-life = 4.26 (~five sessions) to reach the plateau of 80% of the estimated acquired knowledge, since 100% of the students have reached this level of skill (Figure-3). From the fifth session till the 10th session, the gain of knowledge was not significant, although some students reached 96% of the expected abilities (Table-3) (Figure-4).

Figure 3 - Learning curve revealing a plateau after the 5th training session on simulator.

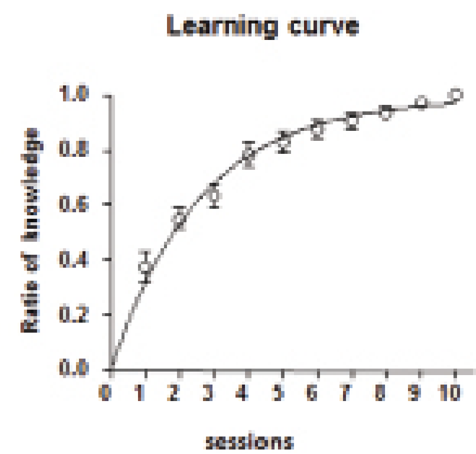


Table 2 - Median scores and quartiles obtained by the group of students in each training session.

Training	N	Missing	Median	25%	75%
Session-1	11	0	40,000	17,500	52,500
Session 2	11	0	58,000	42,000	63,750
Session 3	11	0	63,000	52,750	71,500
Session 4	11	0	79,000	65,750	89,000
Session 5	11	0	85,000	74,500	94,250
Session 6	11	0	87,000	82,000	99,500
Session 7	11	0	91,000	84,250	99,500
Session 8	11	0	95,000	88,250	100,000
Session 9	11	0	100,000	96,500	100,000
Session 10	11	0	100,000	100,000	100,000

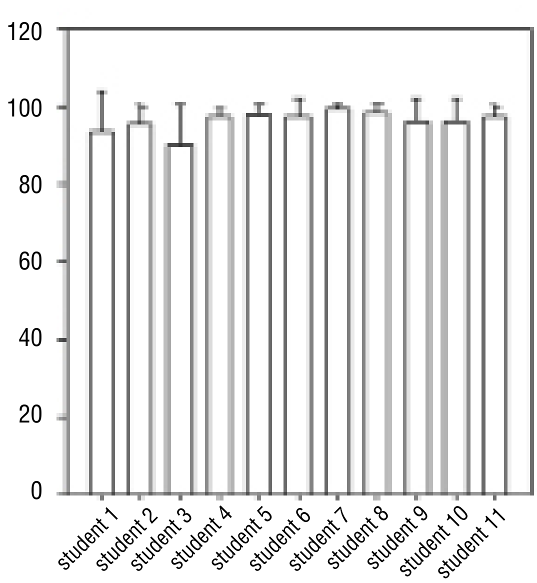
Friedman Repeated Measures

Chi-square = 104,139 with 10 degrees of freedom. (P = < 0.001)

Table 3 - To isolate the group or groups that differ from the others a multiple comparison versus control group procedure by Dunnett`s method was performed revealing that after the fifth session no significant difference of score ranks was observed.

Comparison	Diff of Ranks	q'	P < 0.05
Session - 1 vs session - 10	95,000	6,107	Yes
Session - 2 vs session - 10	76,000	4,885	Yes
Session - 3 vs session - 10	69,000	4,435	Yes
Session - 4 vs session - 10	50,500	3,246	Yes
Session - 5 vs session - 10	41,500	2,668	No
Session - 6 vs session - 10	29,000	1,864	Do Not Test
Session - 7 vs session - 10	21,000	1,350	Do Not Test
Session - 8 vs session - 10	17,000	1,093	Do Not Test
Session - 9 vs session - 10	6,500	0,418	Do Not Test

Figure 4 - Performance results of each student after 10 training sessions. All students reached the score of 80% of success, being 98% the maximum score value.



DISCUSSION

The capacitation of novice surgeons has evolved along the years. The advances of the minimally invasive techniques that the trainees should be exposed to, the ethical aspects of practicing surgery in human subjects and the shortening of the residence periods of training, have raised the need to elaborate a complete and compact learning program (7).

The employment of virtual simulators in these educational programs may be an useful tool for capacitation of these novices surgeons, avoiding the exposition of human patients to non-expert hands in initial phases of training. Furthermore, as long as the noninvasive techniques and devices get improved, the simulators are able to follow the innovations and to promote an updated training experience. They also allow the trainees to practice whenever they want (8,9).

The educational institutions aim to elaborate a surgery learning program which includes virtual reality and animal models. With the shortening of training schedules, it is essential to spend this time in a wise and productive way (10).

Our goal was to define how many virtual reality training sessions were necessary to the medical students to reach a plateau in a specific task. The virtual simulators are able to analyze in a precise way the time spent to perform the tasks, economy of movements, skill, the path course and the intensity level of the task during the training sessions (8).

Hogle et al. reported that after 7 to 8 training sessions the students did not reach the plateau level in navigation, coordination, grasping, peg, transfer, cut and clipping, with the Lap Sim device (11).

The learning curve can be defined as the graphic representation of the abilities acquired until a plateau of knowledge similar to the experts is reached (12).

Although simulation is a technique of reproducing a real situation with an improvement proposal, it is necessary to point out that the success on learning is more related to individual efforts than to an established number of sessions (13). Systematic reviews have shown that the performance of naive students in laparoscopy has better results in timing, precision and less errors after previous training (14-19).

After reaching the excellence level in a determined task, the trainee is able to move forward, to a more difficult level. Time to complete a task is also computed. So, when you elaborate a training program, it is more important to define a point of expertise to be reached than the number of hours of training (20). In this study we proposed ten training sessions, however 100% of the students reached 80% of their capacitation after five times and it was considered the plateau of the learning curve. However, some of them reached a 96% index of success, an indication that a small but continuous improvement of skills is still possible to be reached. Future studies should include more complexes tasks.

Despite the great number of studies on this subject, a consensus on a validated simulation system is still missing. An international consent must also be defined in order to uniform the training and assessment techniques (21). Recently, The European Endoscopic Surgery Consensus recommended that the basic laparoscopic surgical tasks should be practiced in a laboratory before the practice on human beings (22). But, although modern simulators are more realistic, it is still hard to transfer the virtual reality skills to surgical practice (21,23,24). LapSim simulators have programs very similar to real surgery, and may be considered an advantageous factor. Van Hove et al. performed a review study on 104 published papers that focused on the progress of the students training on simulators and concluded that these equipments are able to assess the progress of the trainee on the simulators activities, but have no capacity to give credentials or evaluate their abilities as a laparoscopic surgeon (5).

We should consider that virtual simulation is a simple tool used to offer training and assessment in basic laparoscopy skills, in this target it can be useful, but getting abilities involve a complex issue. The costs of the VR system is a relevant disadvantage that has to be concerned when establishing a training center. Another issue to be pointed out is the question about the transferability of these skills into clinical practice, as well as the questionable ability of students or even surgeons to retain the skills once practice sessions are discontinued. The goal of this study was to establish the shortest training period with virtual reality simulator able to promote laparoscopic basic skills achievement to naïve students or even laparoscopy beginners.

In summary, although innovatory simulators are in continuous improvement, proficiency criteria, learning curves definition and validation of skills certification must be pursued by all those involved on laparoscopic training and medical education.

CONCLUSIONS

This study revealed that after five virtual reality simulator training sequential sessions the students' learning curve reaches a plateau. To stay in the same difficult level does not promote any improvement in basic laparoscopic surgery skills, and the students should be introduced to more difficult training tasks.

CONFLICT OF INTEREST

None declared.

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